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in the quantity of water delivered. Spring floods will carry heavy pebbles farther than the weaker currents of autumn can. Hence, at any given spot, a cross-section of the fan will also show annual vertical variations in the texture of the sediments.

From the foregoing account, the inference is obvious that the fan is growing and that, in so doing, it is filling the lake. This is indicated by the five facts already explained: (1) the surface of the fan is dissected by channels of *recent* formation; (2) the weaker stream has been pushed against the valley wall; (3) the deposits are fresh, and the vegetation is consequently sparse; (4) the lake and the fan are in the same depression; and, (5) the structural relation between the lake and the fan is that of a filling lake basin. To-day Emerald Lake appears to be about half its original size.

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## ON THE NATURE OF MAPS AND MAP LOGIC.\*

BY

DR. MAX ECKERT.

Translated by W. JOERG.

"Maps are the basis of geography."

"Maps represent the deposit of geographic knowledge for any given period."

"Maps are the indispensable tools and implements of geography and geographic teaching."

These and similar sayings of eminent geographers and thinkers have greatly stimulated geographic thought and have raised maps to a higher position than that usually occupied by illustrative material in other sciences. They are no longer merely considered as aids that require the addition of descriptive text to portray adequately geographic phenomena, but as products of scientific research which, being complete in themselves, convey their message by means of their own signs and symbols and through these furnish the basis for further geographic deduction. Emil von Sydow expressed this thought fifty years ago; its truth, however, is often not yet sufficiently realized.

This special function of maps in geography calls for a detailed investigation of their properties, as revealed by a study of their con-

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\* Abstract of a paper read before the German Geographical Meeting at Nuremberg, May, 1907.

tents, their methods of representation, their scope and their various purposes. That one of the main duties of cartography is to investigate the nature of maps has been recognized by many writers on the subject, such as Tissot and Hammer, who, in their critical treatises on projections, H. Fischer and E. Friedrich in their essays on the philosophical phase of cartography, Haack in his critique of maps, and Peucker in his article on the adequate representation of relief, have done much to raise cartography to the standard of a science.

Undoubtedly the most important object of maps is to portray on a plane the surface of the earth or some larger or smaller portion of it. Although it is impossible to represent correctly upon a plane the surface of the sphere, maps, because they indicate the relative position of geographic objects, lend themselves to measurements and comparisons the resultant values of which are equivalent to those of the surface of the sphere. But these values are correct only for two-dimensional terrestrial phenomena; with regard to relief their accuracy is limited, because of the impossibility of reproducing the three-dimensional extent of space on the two-dimensional one of the plan. Petermann, who is generally accused of an exaggerated estimation of the value of maps, was fully conscious of their limitations, for, in the introduction to his review of map publications in the first volume of the "*Geographisches Jahrbuch*," he uses the words: "The information that all of our maps convey is purely relative."

To test the quality of a map is to determine how well it has solved the geometric problem imposed upon it of reproducing constructively the distribution in space of geographic objects. Due allowance should be made, however, for the actual state of geographic knowledge and for the scale and purpose of the map, as these are the factors that determine the number and extent of geographic features to be represented on it.

Just as, furthermore, a good portrait of a person gives us a clue to his past life, so maps should, to a certain extent, give an insight into the genetic history of our earth. But this alone is not sufficient; for the surface of the earth is not only a resultant of inner and outer physical forces: it is also modified by organic agencies. To reproduce the traces which organic life and, particularly, man leave upon it should form one of the main aims of map-making. One might almost say that maps showing the economic and commercial phenomena of any given region constitute a graphic epitome of our geographic knowledge concerning that region.

In this sense topographic maps are the maps that contain the most complete exposition of the facts the geographer needs. They

are preëminently suited for detailed investigation. It is therefore inadvisable to speak of geographic, in contrast to topographic, maps, as is done in many schemes of classification. Topographic, chorographic, and survey maps should be called geographically concrete maps, because they reproduce facts as they exist in nature, such as the distribution of land and water and of heights and depressions. Their antitheses are the geographically concrete maps, which separate the incidental from the essential and express it in a generalized form. They present, in cartographic form, the results of scientific induction and deduction and, in most cases, can be traced back to the study of the scientist. To this class belong all general economic, commercial, statistical, ethnographic, population, and physical maps. Geographically abstract maps are, owing to their nature, usually drawn to a small scale. No definite division, however, can be made between the two groups, for they merge into each other; population maps in the form of settlement maps become concrete, while physical maps when drawn to small scale become abstract.

One of the principal domains of geography is that of measuring, a fact Hermann Wagner has frequently emphasized. Measurements are in many cases best made on maps. To what extent a map is suited to be used as a basis for measurements can only be determined by a thorough knowledge of the properties of map projections, particularly concerning conformability and equivalence. In this connection it is especially necessary to call attention to the fact that the Mercator map, which is, par excellence, the map of the navigator, is in most cases unsuited to the purposes of the geographer, for the geographer is mainly interested in the comparison of areas and for that reason requires an equivalent projection.

Closely allied to the question of the nature of maps is that of their artistic value. Can cartography in any way lay claim to the designation of art? Opinions on this point are divided, but the majority of authorities on the subject recognize the existence of an artistic beside a scientific element in cartography. Ernst Debes, one of Petermann's foremost followers, for instance, begins a treatise on map-making with the words: "The *art* of drawing maps is called cartography."

It is evident that cartography is not merely a technical art. It is for the greater part an applied art, an art governed and determined by scientific laws. But how can cartography avoid the rigid rules of mathematical precision? The decisive turning-point, according to my opinion, lies in the transition from the topographic to the general map. As long as the scale allows the objects in nature to be repre-

sented in their true proportion on the map, technical skill alone is necessary. Where this possibility ends the art of the cartographer begins. With generalization art enters into the making of maps.

In generalizing lies the difficulty of scientific map-making, for it no longer allows the cartographer to rely merely on objective facts but requires him to interpret them subjectively. To be sure the selection of the subject matter is controlled by considerations regarding its suitability and value, but the manner in which this material is to be rendered graphically depends on personal and subjective feeling. But the latter must not predominate: the dictates of science will prevent any erratic flight of the imagination and impart to the map a fundamentally objective character in spite of all subjective impulses. It is in this respect that maps are distinguished from fine products of art. Generalized maps and, in fact, all abstract maps should, therefore, be products of art clarified by science.

If cartography were devoid of art it would sink to the level of a mere handicraft, as is evidenced even to-day in many map products of inferior quality. On the other hand, an artistic appearance, particularly a pleasing colouring, can deceive in regard to the scientific accuracy of a map. The ideal is the intimate union of the scientific spirit with artistic execution, and when this is realized it produces those maps which for years remain models of their kind.

The artistic quality is most evident on maps showing relief. From the point of view of art it could be said: well-executed relief maps embody an esthetic purpose, for they are intended to make an agreeable impression upon the observer. But they are again different from pure products of art in that the creation of an agreeable impression is not their main purpose, this being, on the contrary, the transmission and dissemination of scientific truths.

Since the time of Dufour the method of oblique illumination has generally been used in the drawing of relief, because, through its distribution of light and shade it best produces the desired plastic effect. Colours are also sometimes used to heighten this effect, as, for instance, bluish tints for mountain shadows. The splendid wall map of Switzerland by Kümmerly is a standard example of this method. Maps showing this treatment of relief have a further characteristic in common with art, viz., illusion. Due to the conceptions of space which have grown up in our consciousness from childhood the impression of an actual mountainous region is awakened in our minds.

The desire to create this illusion explains the preference given in elementary geographical teaching to maps drawn in the manner of

models. Many of our cartographers do not understand how maps with so crude a representation of relief, and only too often lacking a scientific basis, can be bought for use in schools. This fact has its psychological reason, as we have just seen. But in more advanced work this sort of illusion on maps should be eschewed.

Of the various methods of representing relief, Lehmann's system of hachures is extensively used. It must be remembered, however, that it is not based on scientific law but that it merely offers a practical solution of the problem. For the intensity of perpendicular rays of light illuminating an oblique surface does not vary in an arithmetic progression, but as the cosine of the angle of inclination of the surface. To my mind even hachures are not flexible enough to express relief adequately; they should be partially supplemented by dots and sometimes even entirely replaced by them. As for contours, it is necessary to warn against an over-valuation of their scientific accuracy—an error easily fallen into on account of the exactitude their nature implies.

Colours are further aids that scientific cartography need not reject. How indispensable they are is shown by the fact that their use has become the rule for physical and anthropogeographical maps. But we may rightfully protest against their indiscriminate and immoderate use, as exemplified by the average popular map. For scientific purposes an esthetically pleasing picture, that loses none of its accuracy, can also be obtained by the use of few colours. Discrimination in the choice of subjects to be represented, right feeling for the receptiveness of the persons for whom the map is intended, and lastly, individual taste should be the determining factors in this matter. Examples of a pleasing treatment of colours are the climatological maps by Supan in *Petermann's Mitteilungen* and the physical maps published by Wagner and Debes; while, on the other hand, a disagreeable impression is produced by the checkered and mottled appearance of many French maps of France and of American maps of the United States, showing the division into departments or into separate states, as the case may be.

In the choice of colours for anthropogeographical and allied maps, logic and not personal taste should be the decisive factor, all the more so as opinions vary widely as to what constitutes good taste in the juxtaposition of colours. I should, therefore, like to designate one of the most important topics that scientific cartography has to deal with: "map logic." Map logic treats of the laws which underlie the creation of maps and which govern cartographic perception. In education the development of the sense of cartographic percep-

tion is the most important, for it comprises the mental reconstruction of the ideas expressed in the symbolism of the map. In its last analysis it is the process of thinking and feeling one's self into the entire subject matter of cartography. The contents of maps, their scale, their symbols, their colouring and the projection on which each of them is drawn are subjected to its scrutiny and judgment is passed on their value.

Let us investigate the question of the choice of colours. Logic here makes two demands of us: that the colours adopted be similar, if possible, to those of the objects in nature to be represented and that the colour scheme be based on physical laws or on pedagogical experience.

Our maps afford many examples of colours that have been copied directly from nature. Such a selection of colours greatly promotes the association of ideas. No one thinks of violating the traditional use of blue for the fluid element, be it liquid or solid (as glaciers). That the sea should be coloured a deeper blue as its depth increases is logical\* for depth is expressed in terms of increasing thickness of the layers of water.

The use of blue for rainfall maps has become general. The transition to violet tints for regions of the greatest rainfall also accords with the laws of colour intensity. To present the driest regions in yellow tints corresponds to natural conditions and facilitates comprehension, for yellow is the colour of sand and of dry soils and, therefore, is suggestive of arid regions. One and the same predominant colour should not be used on maps which represent different phenomena of the same region, such as temperature and rainfall, for instance, as this leads to confusion. Different colour schemes should be used for each map in cases of this kind.

It is a well-known fact that blue is a cold and red a warm colour. This contrast, which has a psychological, as well as a physiological, reason, should be taken advantage of in temperature maps. If a map of the temperature on land is combined with one of the ocean currents a certain concordance in the colour scheme should be established. I have before this pointed out that it is not correct to use yellow or green for the torrid zone and red or other colors for the frigid zone if the warm currents have been represented in red and the cold ones in blue or green. Logic requires the use of shades of the same colour to depict allied phenomena.

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\* The recognition of the truth of this fact seems to have led the editors of *Andree's Handatlas* to abandon the opposite method in the present (5th) edition of the Atlas, after having employed it in the previous edition and in contemporary map publications.—W. J.

That green has mainly been used on maps dealing with plant geography is natural and needs no further comment. An interesting example of the logical use of colours has recently been furnished by Roesle's general map of diseases in the German Empire, on which the distribution of measles is represented in pale red, of scarlet fever in bright red, of cholera in a dirty shade of brown and of tuberculosis in blue.

The geographer, however, needs many colours for which he finds no direct analogies in nature. When this is the case the colour scheme should not be decided upon without reflection, and particular attention should be paid to the question whether the map under consideration is intended to be a wall map, which must be effective at a distance, or a map for detailed study near at hand. For wall maps contrasting colours should be chosen, except in the representation of relief. Red and blue are particularly in favour and very effective. For maps intended for use close at hand the various shades and tints of the same colour are to be preferred. This is particularly the case with maps showing density of population; these should not be suggestive of the multicoloured appearance of a geological map.

A good basis for the selection of colours which are to express a definite sequence is furnished by the spectrum. A partial application of this idea has first been carried out on geological maps. Various schemes have been suggested and used, but the standard has been established by the decision of the Geological Congress at Bologna in 1881 and been applied to the International Geological Map of Europe on the scale of 1:1,500,000. On this map Devonian formations are coloured brown, Carboniferous, gray, Triassic, violet, Jurassic, blue, Cretaceous, green and Tertiary, in shades of yellow, while granites appear in shades of red and recent eruptive rocks in vermillion.

The use of spectrum colours has also been advocated to represent relief; but although the original suggestion made by Hauslab to this effect has been extended and mathematically developed by Peucker this method has so far not found a widespread application.

As an example of a relief map of unique and, in its way, very pleasing appearance, I should like to call attention to Bartholomew's Map of the Surface Relief of England and Wales, published in the *Geographical Journal* for December, 1904. On it the lowlands are represented in shades of green, the highlands in shades of violet.

I should, furthermore, not consider it impracticable to adopt for certain representations of relief a more obvious colour scheme than those used heretofore. For instance, on a contour map of the

Cordillera of Bogotá, red could be used to represent the Tierra Caliente, brown for the Tierra Templada, and blue for the Tierra Fria. In this way temperature and relief would go hand in hand.

How far the use of a logical colour scheme is evident on anthropogeographical and allied maps I shall not attempt to discuss here, as a treatment of this theme, to be in any way of value, would carry me too far. But I should like to say—an opinion which many share with me—that many of our economic maps, apart from their technical inferiority, are woefully lacking in colour logic and a critical selection of their subject matter.

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## GEOGRAPHICAL RECORD.

### AFRICA.

THE KOMATI POORT COALFIELD.—The Geological Survey (Transvaal Mining Department) has begun the publication of a series of descriptive Memoirs dealing with special areas of the Transvaal. The second of this series, entitled "The Geology of the Komati Poort Coalfield," gives a connected account, including geological maps and sections, of the character, behaviour, and distribution of the coal-bearing strata of that district. The author, Mr. H. Kynaston, Director of the Geological Survey, also describes the associated sedimentary and igneous rocks and the general relations, position and age of the entire series. There is little doubt that the coal is a sedimentary deposit consisting of the fragmentary remains of the luxuriant vegetation which flourished during portions of the Karroo period in South Africa. The principal drawback is the prevalence of intrusive sheets and dikes of igneous rock throughout the coal-bearing strata. The prevailing character of the coal is anthracitic. The field occupies about 150 square miles. The great thickness of the coal-bearing strata, the promising nature of the early results and the accessibility of the northern and perhaps better part of the field give a satisfactory aspect to the economic proposition.

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### AMERICA.

WORK OF THE COAST AND GEODETIC SURVEY.—In the report of the Superintendent for 1907, the results of the investigation of the earth's figure, based on geodetic operations in the United States, are merely mentioned because they were communicated to the International Geodetic Association in a report which has been published.

The thorough test of nickel-steel (invar) tapes for the measurement of primary bases has demonstrated that the adoption of these tapes in place of the steel tapes formerly used is a distinct advance in base measurement. It is much less difficult to keep the temperature errors within the required limit with invar than with steel tapes.

Throughout the year the measurements of the earth's magnetism were made